Muon g−2 Experiment

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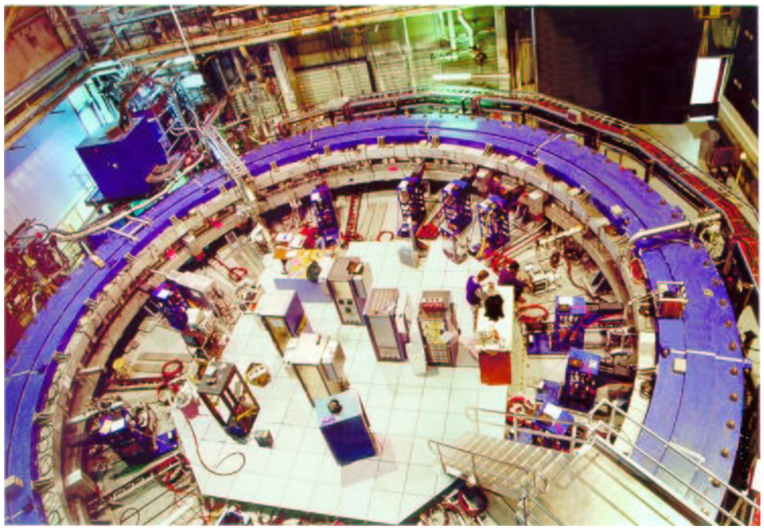
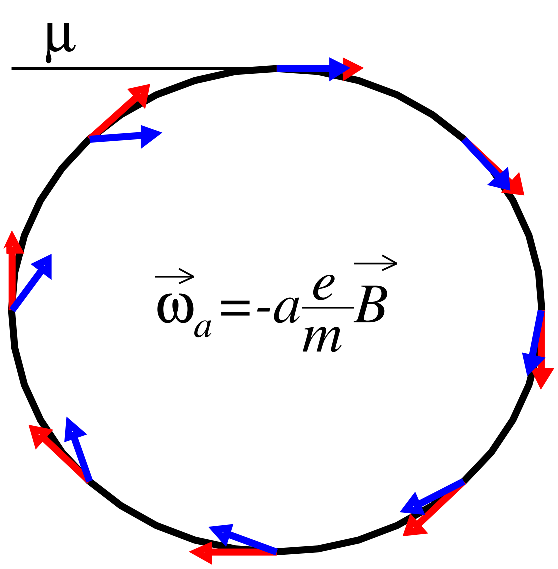




$$\omega_c = \frac{eB}{mc\gamma}$$

$$\omega_s = \frac{eB}{mc\gamma} + \frac{e}{mc}aB$$

$$\omega_a = \omega_s - \omega_c = \frac{e}{mc}aB$$

$$\omega_a = \frac{e}{mc}[aB - \underbrace{\left(a - \frac{1}{\gamma^2 - 1}\right)}_{\sim 0 \;\; for \;\; \gamma \simeq 29.3}(\vec{\beta} \times \vec{E})]$$

$$\mu^+ \to e^+ + \nu_e + \bar{\nu}_\mu$$

$$N(t) = N_0(E)e^{-t/\gamma\tau}[1 + A(E)\sin(\omega_a t + \phi(E))]$$

where $N(t)$ is the number of decay positrons with energies greater than E.

$$a_\mu = \frac{\omega_a/\omega_p}{\mu_\mu/\mu_p - \omega_a/\omega_p}$$

Goal of AGS Muon g-2 Experiment

Measure $a_\mu = \frac{g_\mu - 2}{2}$ for the muon to 0.35 ppm.

Hence our AGS experiment aims for an improvement by a factor of 20 compared to the CERN result.

Although the electron g-2 value is known to about 3 ppb, the muon g-2 value is more sensitive to non-QED contributions at high mass scales, typically by a factor of $(m_\mu/m_e)^2 = 4 \times 10^4$.

Physics Motivation

- Determination $a_\mu(\text{weak}) \approx 1.3$ ppm to about 25% accuracy.

  A contribution from loop diagrams involving virtual W and Z which tests renormalizability of electroweak theory.

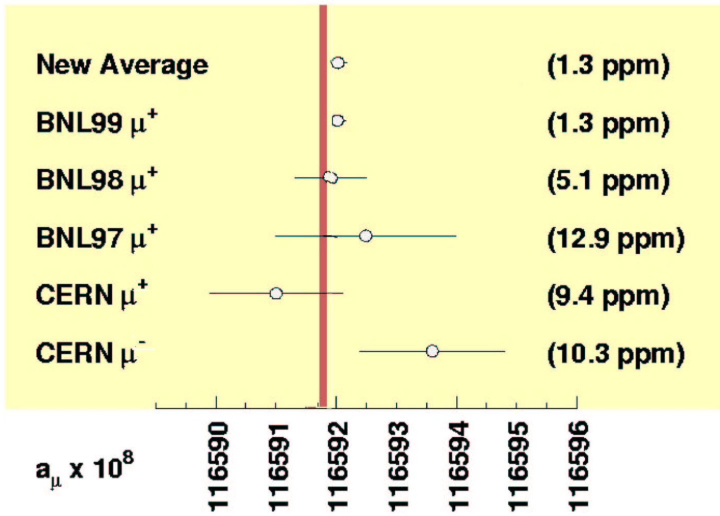
- Physics Beyond the Standard Model

  $a_\mu(\text{theory})$ based on the standard theory is a sum rule for known physics. A deviation of $a_\mu(\text{expt})$ from $a_\mu(\text{theory})$ indicates new physics, such as lepton substructure, W anomalous magnetic moment, supersymmetry, leptoquarks, new particles, or extra dimensions. However, g-2 by itself can not determine the specific cause of such a deviation. Agreement of $a_\mu(\text{expt})$ and $a_\mu(\text{theory})$ places constraints on speculative new theories.

A precision measurement of a_μ provides *unique* and *sensitive* information which is complementary to that from high energy collider experiments.

Status of Muon $g-2$

- Experiment:



$$a_{\mu^+}(\text{expt}) = 11\,659\,202(14)(6) \times 10^{-10} \quad (1.3\text{ ppm})$$

- Theory:

$$\begin{aligned}
a_\mu(\text{SM}) &= a_\mu(\text{QED}) + a_\mu(\text{had}) + a_\mu(\text{weak}) \\
a_\mu(\text{QED}) &= 11\,658\,470.56(0.29) \times 10^{-10} \quad (25\text{ ppb}) \\
a_\mu(\text{had}) &= 673.9\ (6.7) \times 10^{-10} \quad (0.57\text{ ppm}) \\
a_\mu(\text{had LL}) &= -\,8.5\ (2.5) \times 10^{-10} \\
a_\mu(\text{weak}) &= 15.1\ (0.4) \times 10^{-10} \quad (0.03\text{ ppm}) \\
a_\mu(\text{SM}) &= 11\,659\,159.6\ (6.7) \times 10^{-10} \quad (0.6\text{ ppm}) \quad 2001 \\
\text{Expt} - \text{SM} &= 43\ (16) \times 10^{-10}
\end{aligned}$$

Error in the theory

$$\begin{aligned}
a_\mu(\text{had LL}) &= +\,8.5\ (2.5) \times 10^{-10} \\
a_\mu(\text{SM}) &= 11\,659\,176.6\ (6.7) \times 10^{-10} \quad (0.6\text{ ppm}) \quad 2002 \\
\text{Expt} - \text{SM} &= 26\ (16) \times 10^{-10}
\end{aligned}$$

Future data–taking run needed

	1999	2000	2001	requested 2002
particle	μ^+	μ^+	μ^-	μ^-
collected $e^\pm$	2.9×10^9	7×10^9	4×10^9	8×10^9
after cuts $e^\pm$	0.95×10^9	4×10^9	3×10^9	6×10^9
statistical error	1.25 ppm	0.61 ppm	0.74 ppm	0.5 ppm
	0.55 ppm (1999–2000)			
systematic error	0.5 ppm	0.4 ppm	0.3 ppm	0.3 ppm

- ✔ Triple the data for μ^-, which is different particle from μ^+.
- ✔ Test CPT. Assuming CPT, reduce the total statistical error.
- ✔ Reduce the systematic error.
- ✔ Same operating mode of the experiment as in 2001.

Conclusion

The muon g-2 collaboration is enthusiastic and ready to obtain the additional data we propose. This is important to complete our experiment with the best precision reasonably possible with our experimental apparatus.

The experiment should be completed regardless of the current theoretical value of g-2 obtained from the standard model, and regardless of the difference, if any, between the experimental and theoretical values of g-2.

We need approval of our proposal at this time else our collaboration will not be maintained and our ability to do the experiment will be lost.

The experimental result on g-2 is of fundamental importance to particle physics. The experiment has no competition now and is unlikely to be done again for many years.